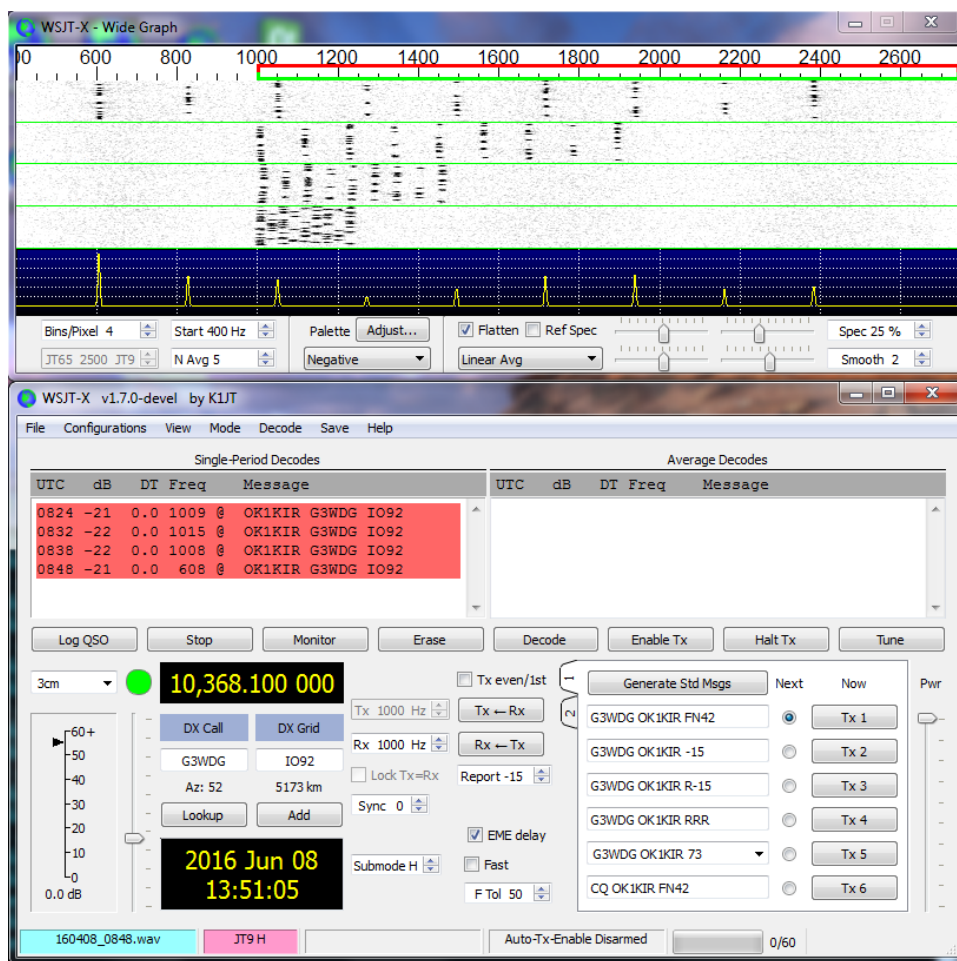


WSJT-X

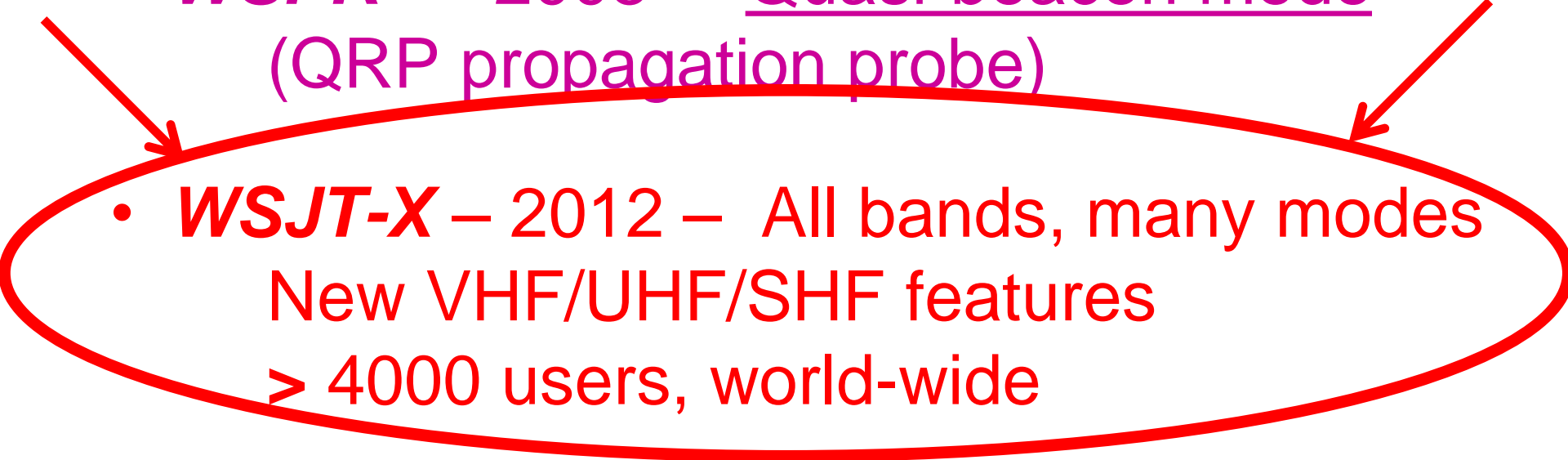
New Codes, Modes and Tools for Weak-Signal Communication

Joe Taylor
K1JT

EME Conference
Venice
Aug 21, 2016



“JT” Weak-Signal Software

- **WSJT** – 2001 – VHF-and-up (meteor scatter, EME, ionoscatter, etc...)
 - **MAP65** – 2006 – Wideband EME (multi-decode, adaptive polarization)
 - **WSPR** – 2008 – Quasi-beacon mode (QRP propagation probe)
 - **WSJT-X** – 2012 – All bands, many modes
New VHF/UHF/SHF features
> 4000 users, world-wide
- 

Codes ? Modes ??

- “Code” – symbols to represent information
 - Character-by-character: Morse (CW), baudot, ASCII, FSK441, ...
 - Block structured: Reed-Solomon, Convolutional, Turbo, LDPC, QRA, ...
- “Mode” – signaling method and protocol:
coding, modulation, symbol rate, block size, ...
 - SSB, CW, FSK441, JT65, JT4, JT9, JTMSK, ...

Block-Structured Messages

Standard minimal QSO

CQ K1ABC FN42

K1ABC W9XYZ EN37

W9XYZ K1ABC -22

K1ABC W9XYZ R-19

W9XYZ K1ABC RRR

K1ABC W9XYZ 73

Minimal QSO with EME “shorthands”

CQ K1ABC FN42

K1ABC W9XYZ EN37

W9XYZ K1ABC FN42 OOO

RO

RRR

73

Relevant VHF+ Propagation Types

Fading rate, depth



- Tropospheric scatter
- Multi-hop (weak) sporadic-E
- EME (VHF, UHF, microwave ...)



slow
shallow

- Ionospheric scatter
- Aircraft scatter
- Meteor scatter



fast
deep

Modes in WSJT-X

Scatter → “Fast”

- ISCAT
- JT9 E-H
- (JTMSK)
- MSK144

EME, QRP → “Slow”

- JT65
- JT4
- JT9
- QRA64
- WSPR

Echo

Mode	Decode
	JT9
<input checked="" type="radio"/>	JT65
	JT9+JT65
	JT4
	WSPR-2
	WSPR-15
	Echo
	ISCAT
	JTMSK
	MSK144
	QRA

Why so many modes?

- Different propagation types
- Code design and parameter optimization for each purpose
 - Fading depth
 - Fading rate (Doppler spread)
 - Frequency stability, sync requirements
- Also important: learning as we go ...

Mode design: Tunable parameters

- Block message structure
- Compression → Source encoding
- Error control coding type and rate
- Information transmission rate
- Modulation type
- Symbol rate → Bandwidth
- Synchronization method

Structured Messages: Design choice for ECC Modes

Information block size: 72 bits

Calls and locator:

KA1ABC WB9XYZ EN37

$$28 + 28 + 15 + 1 = 72$$

Free text:

TNX BOB 73 GL

$$71 + 1 = 72$$

Selected Mode Parameters

Mode	Block Code (k,n)	Q	Modulation	Symbol Rate (Hz)	Sync Fraction	Message Length (s)
JT4	206,72	2	4-FSK	4.375	0.50	47.1
JT9	206,72	8	9-FSK	1.736	0.19	49.0
JT65	63,12	64	65-FSK	2.692	0.50	46.8
QRA64	63,12	64	64-FSK	1.736	0.25	48.4
JT9H fast	206,72	8	9-FSK	200	0.19	0.425
JTMSK	198,72	2	MSK	2000	0.15	0.117
JTMSK sh	24,12	2	MSK	2000	0.31	0.018
MSK144	128,72	2	MSK	2000	0.11	0.072
MSK144 sh	32,16	2	MSK	2000	0.20	0.020

WSJT-X: Recent Advances

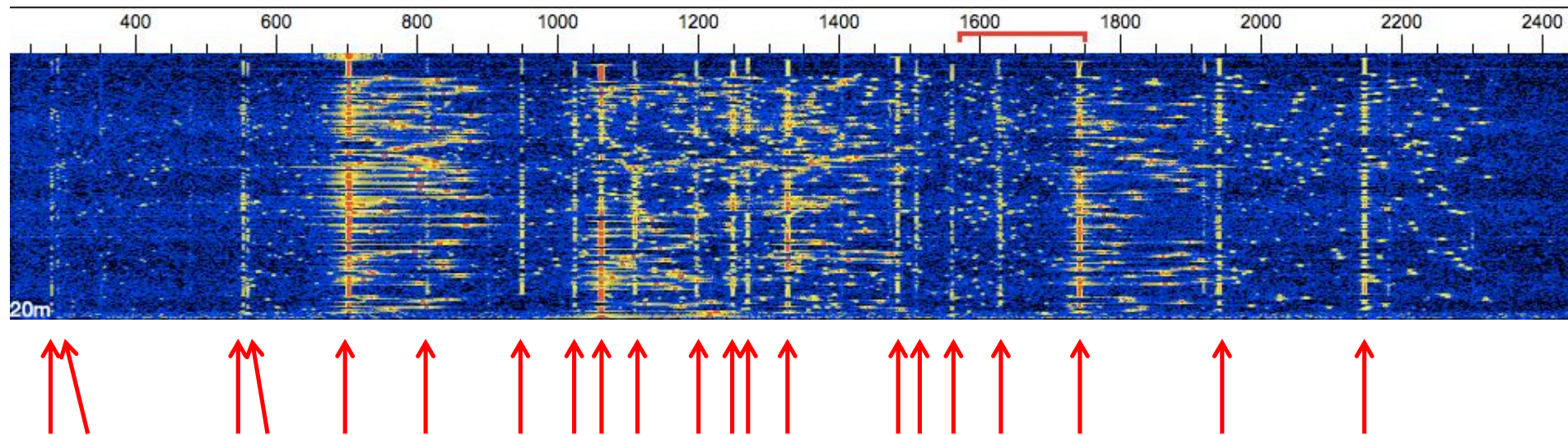
- Platform independence (Windows, Linux, OS X, ...)
- Rig control for nearly all radios
- Accurate frequency calibration
- Franke-Taylor decoder for JT65
- Other decoder improvements
- Added modes: WSPR, fast/wide JT9, JT4, (JTMSK), MSK144, QRA64

Franke-Taylor Decoder for JT65

- Published in *QEX* for May-June 2016
(link on WSJT web site)
- Soft-decision algorithm
- Performs better than Kötter-Vardy
(patented KVASD no longer used)
- As implemented in *WSJT-X*, includes
multi-pass decoding
- Fully open source, GPL v3 license

Franke-Taylor Decoder

← 2 kHz →



↔
177 Hz

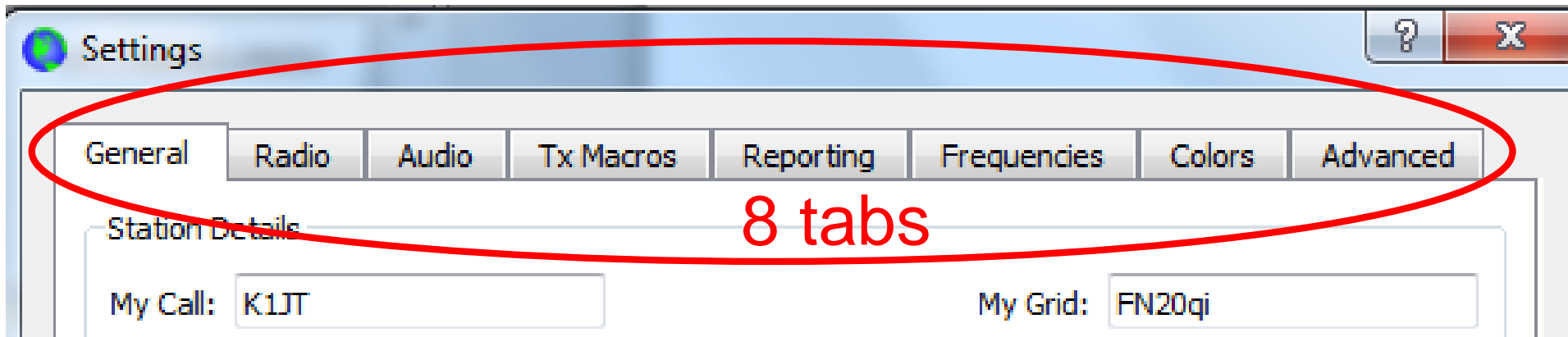
21 JT65A signals, all decoded !

New VHF+ Features in *WSJT-X*

- Transverter offsets
- Automatic EME Doppler tracking
- JPL/NASA planetary ephemeris
(Moon position and Doppler tracking)
- Enhanced Echo mode
- MSK144, QRA64 modes
- Auto-sequencing for fast modes

... Brief guided tour, mostly EME ...

WSJT-X Configuration

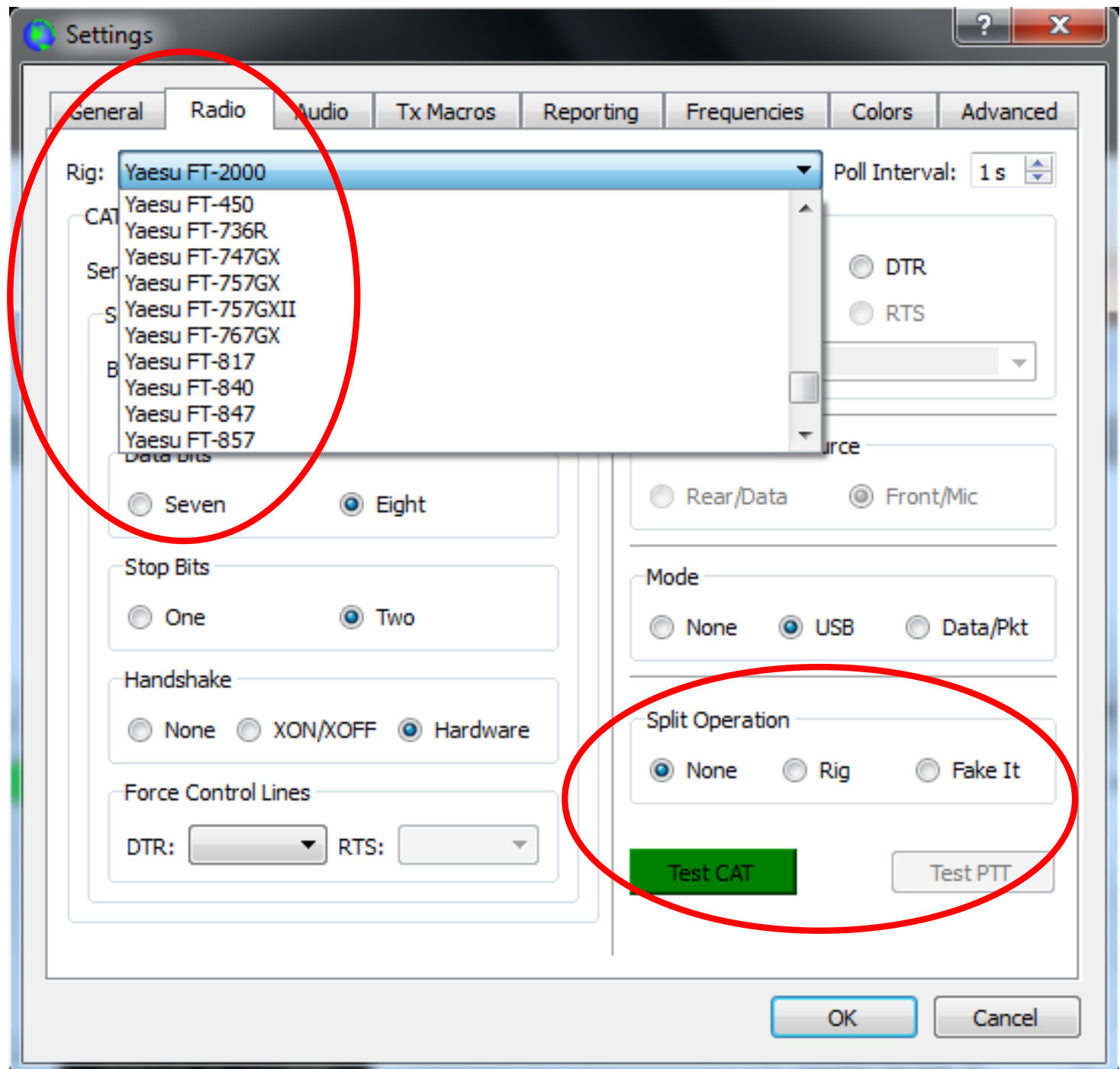


8 tabs

- ☒ Enable VHF/UHF/Microwave features
- ☒ Allow Tx frequency changes while transmitting
- ☒ Single decode
- ☐ Decode at $t = 52$ s
- ☒ Rx frequency offset with "CQ nnn ..."

VHF+ items

Rig Control



Frequency Settings

Settings

General Radio Audio Tx Macros Reporting Frequencies Colors Advanced

Working Frequencies

Mode	Frequency
Echo	10,368.000 000 MHz (3cm)
JT9	10,368.100 000 MHz (3cm)
JT65	10,368.100 000 MHz (3cm)
JT4	10,368.100 000 MHz (3cm)
Echo	24,048.000 000 MHz (1.25cm)

Reset

Frequency Calibration

Intercept: 1.62 Hz

Slope: 0.6317 ppm

Station Information

Band	Offset	Antenna Description
13cm	0.000 000 MHz	
9cm	0.000 000 MHz	
6cm	0.000 000 MHz	
3cm	-10,318.000 000 ...	
1.25cm	0.000 000 MHz	

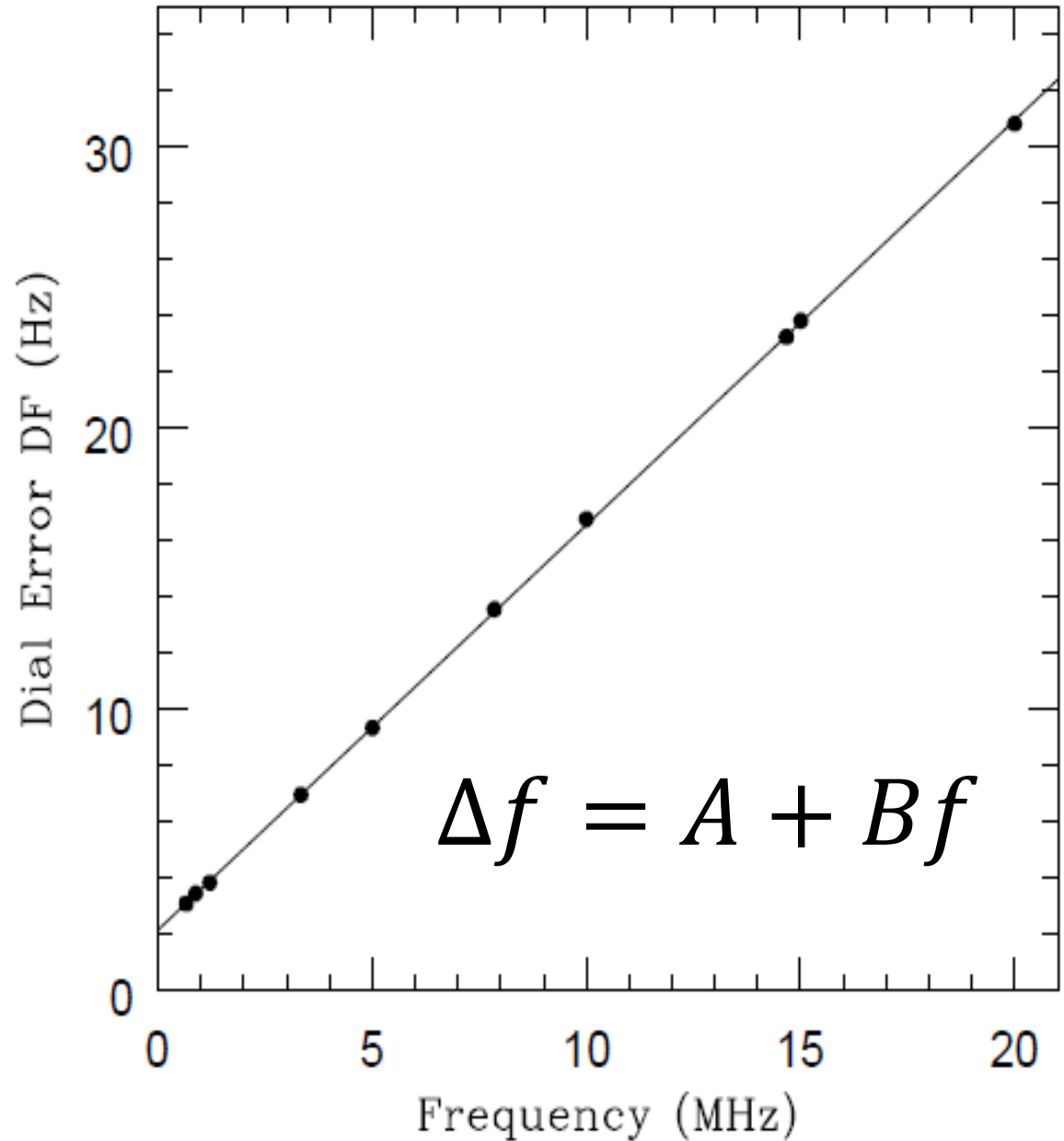
OK Cancel

Calibration
parameters

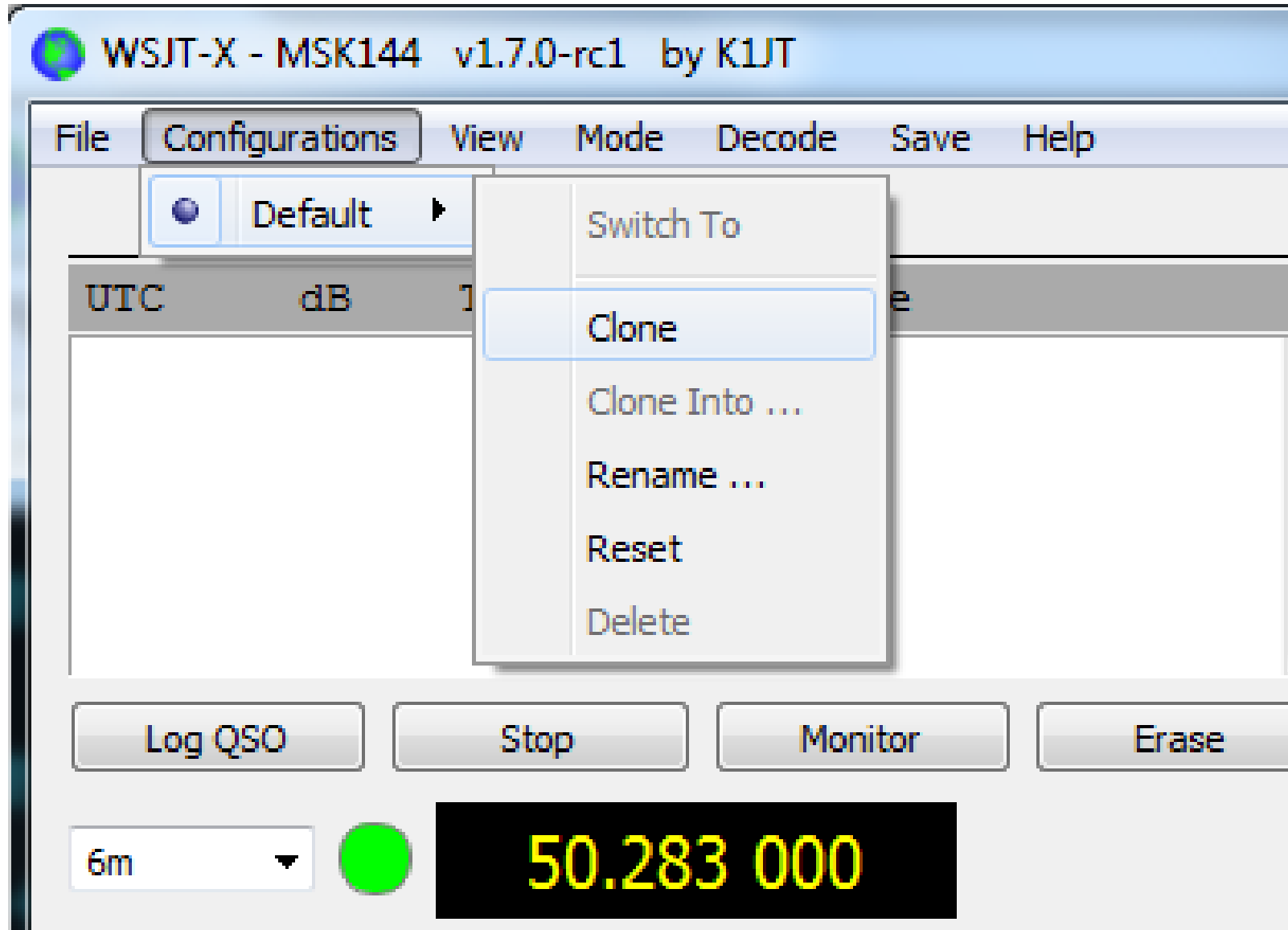
Frequencies
by Mode &
Band

Transverter
offsets

TS-2000X Frequency Calibration



Save/Restore Configurations



Automatic Doppler tracking

WSJT-X - Astronomical Data

2016 Apr 14
UTC: 14:27:52
Az: 45.3
El: -21.2
SelfDop: 11181
Width: 179
Delay: 2.60
DxAz: 52.3
DxEI: -13.2
DxDop: 11870
DxWid: 165
Dec: 15.4
SunAz: 122.0
SunEl: 44.7
Freq: 10368
Tsky: 3
MNR: 0.0
Dgrd: -1.7

Doppler tracking

☐ Full Doppler to DX Grid
☐ Receive only
☒ Constant frequency on Moon
☐ None

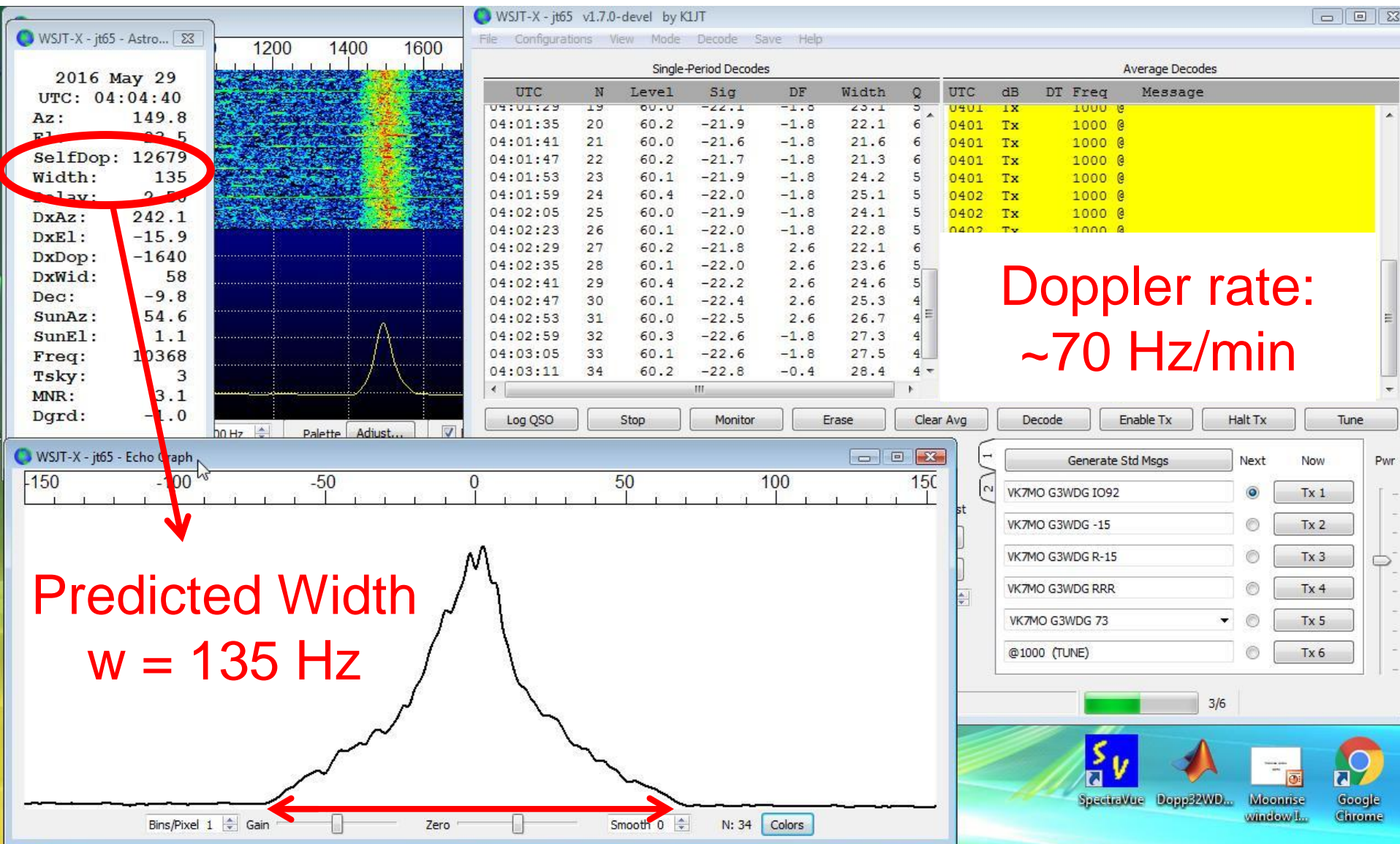
Sked frequency

Rx: 10,368.100 000
Tx: 10,368.100 000

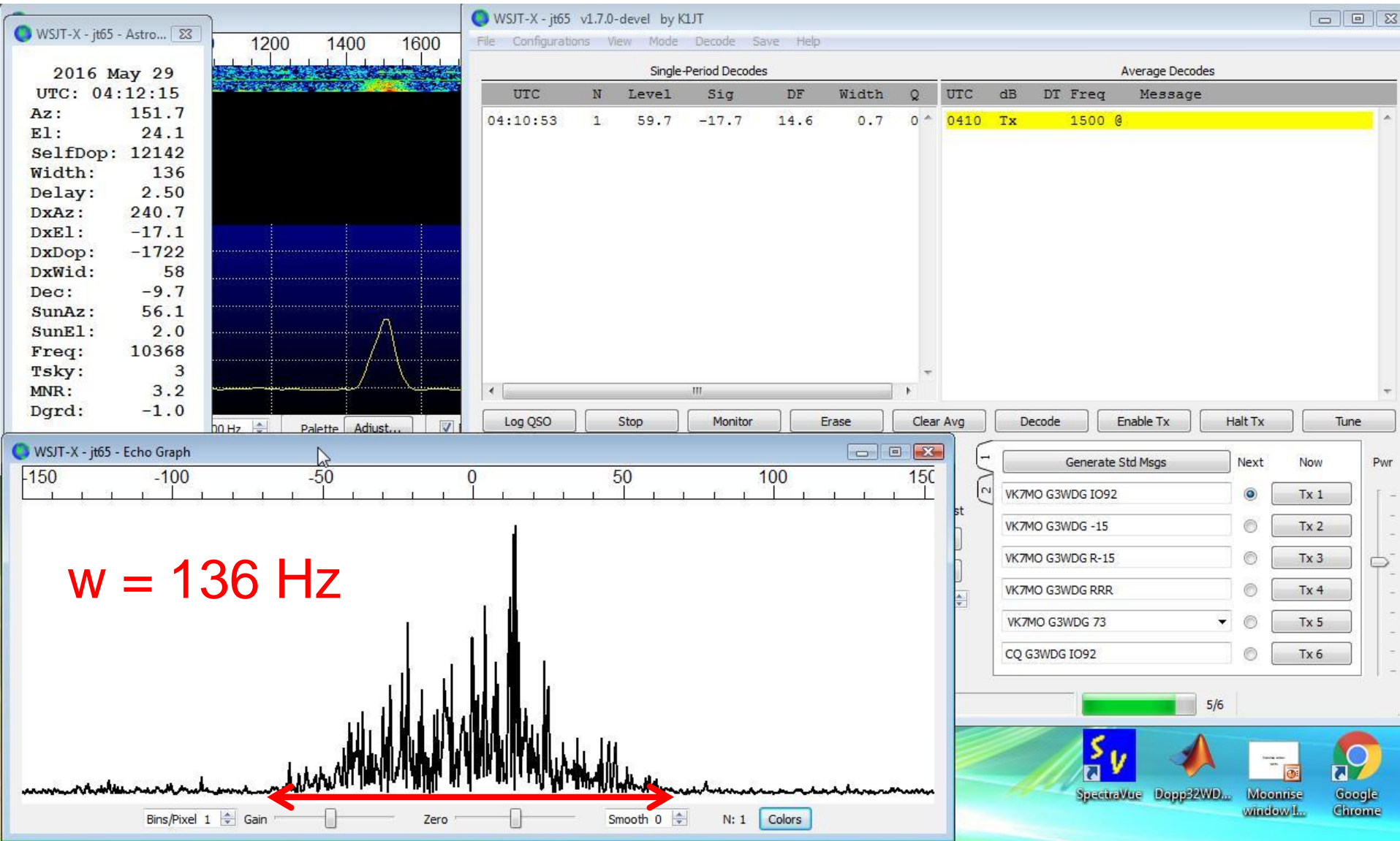
Press and hold the CTRL key to
adjust the sked frequency manually
with the rig's VFO dial or enter
directly into the band edit.

☒ Doppler tracking

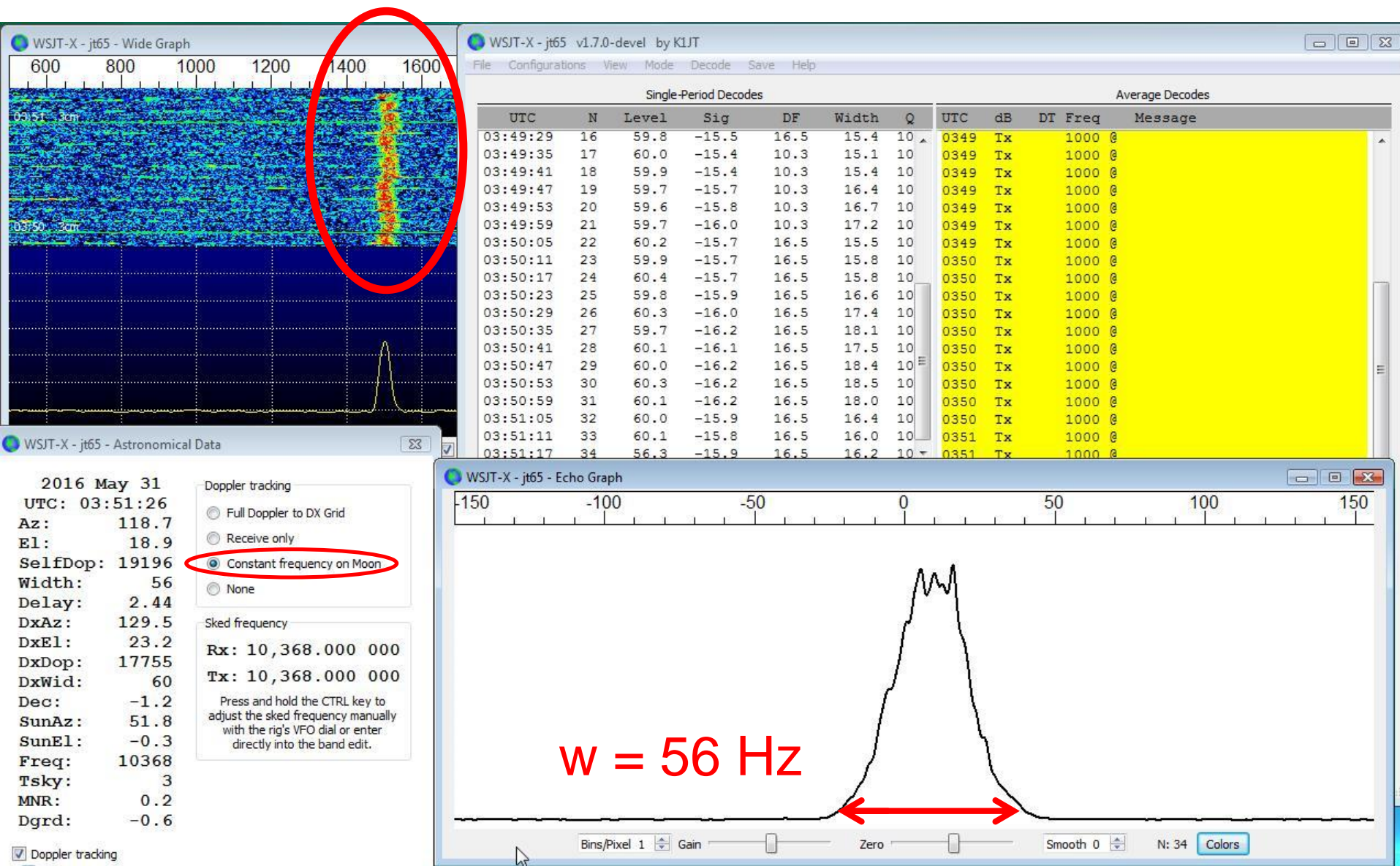
Echo Mode: G3WDG, 10 GHz



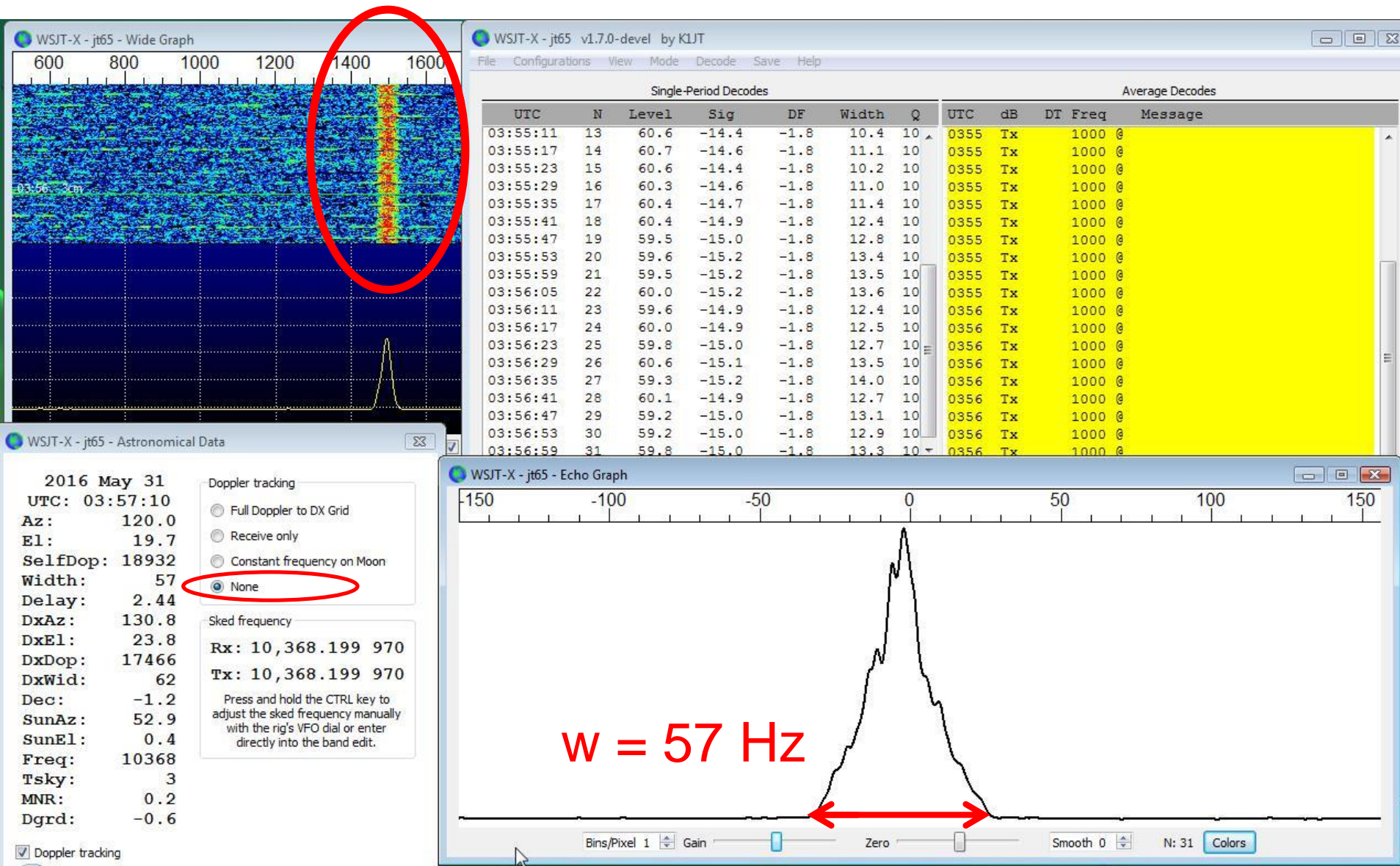
Single-pulse Echo



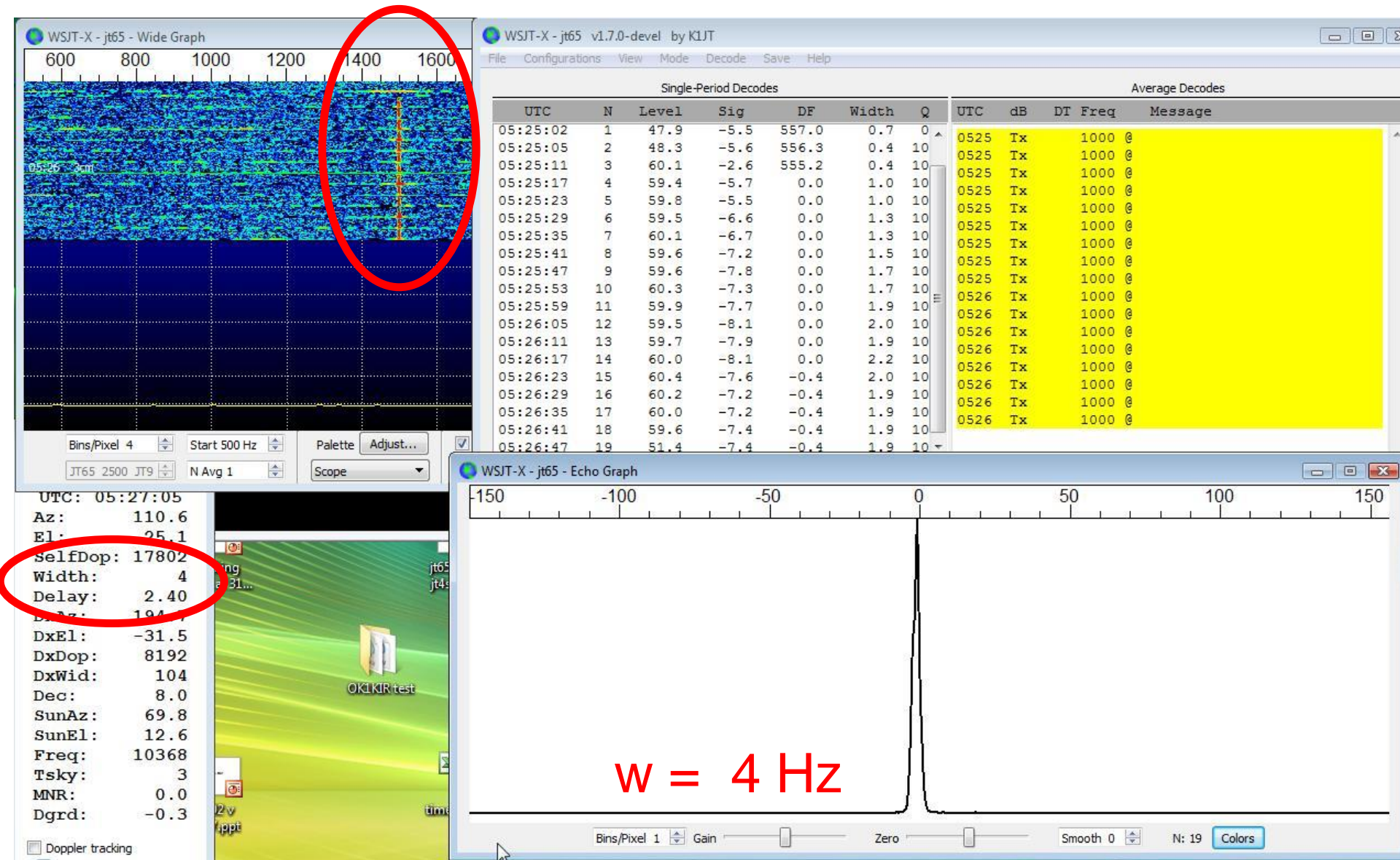
Doppler steering via Rig Control



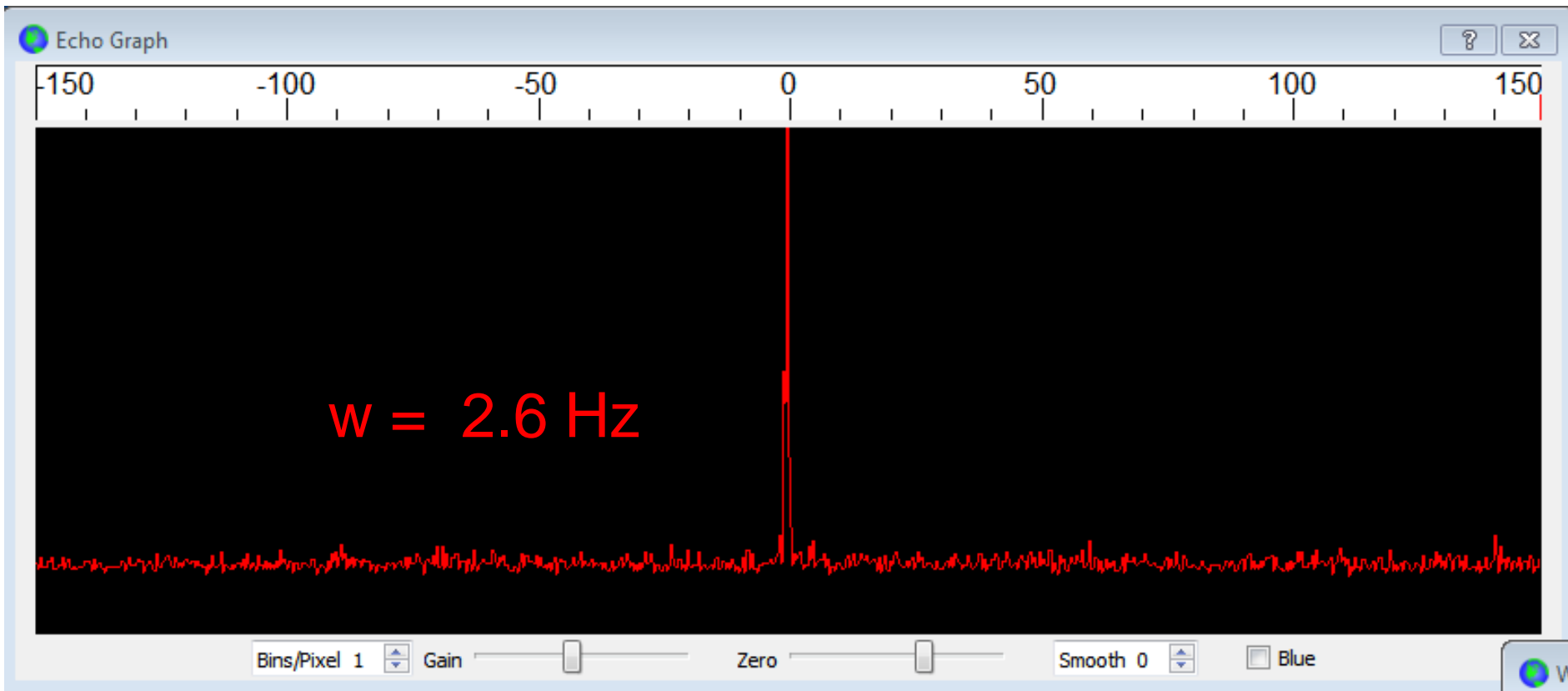
Doppler steering via transverter LO



Close to libration minimum



Echo Mode: K1JT, 144 MHz



Comic relief: JTMSK self-echoes

WSJT-X - jtmsk v1.7.0-devel by K1JT

File View Mode Decode Save Help

Band Activity

UTC	dB	T	Freq	Message
180750	4	1.3	1500	& K1JT G3WDG IO92
180800	9	1.8	1500	& K1JT G3WDG IO92
180810	6	1.5	1504	& K1JT G3WDG IO92
180820	4	1.6	1500	& K1JT G3WDG IO92
180830	7	1.3	1500	& K1JT G3WDG IO92
180840	8	1.9	1500	& K1JT G3WDG IO92
180850	8	1.4	1504	& K1JT G3WDG IO92

Rx Frequency

UTC	dB	T	Freq	Message
180755	Tx		1500	& K1JT G3WDG IO92
180805	Tx		1500	& K1JT G3WDG IO92
180815	Tx		1500	& K1JT G3WDG IO92
180825	Tx		1500	& K1JT G3WDG IO92
180835	Tx		1500	& K1JT G3WDG IO92
180845	Tx		1500	& K1JT G3WDG IO92
180855	Tx		1500	& K1JT G3WDG IO92
180905	Tx		1500	& K1JT G3WDG IO92
180915	Tx		1500	& K1JT G3WDG IO92

Log QSO

Stop

Monitor

Erase

Decode

Enable Tx

Halt Tx

Tune

3cm

10,368.000 000

DX Call

DX Grid

K1JT

Lookup

Add

2015 Nov 23 18:09:42

T/R 5 s

Tx even/1st

Report -15

CQ Rx 285

Auto Seq

F Tol 200

Generate Std Msgs

Next

Now

Pwr

K1JT G3WDG IO92

K1JT G3WDG -15

K1JT G3WDG R-15

K1JT G3WDG RRR

K1JT G3WDG 73

CQ G3WDG IO92

Tx 1

Tx 2

Tx 3

Tx 4

Tx 5

Tx 6

Receiving

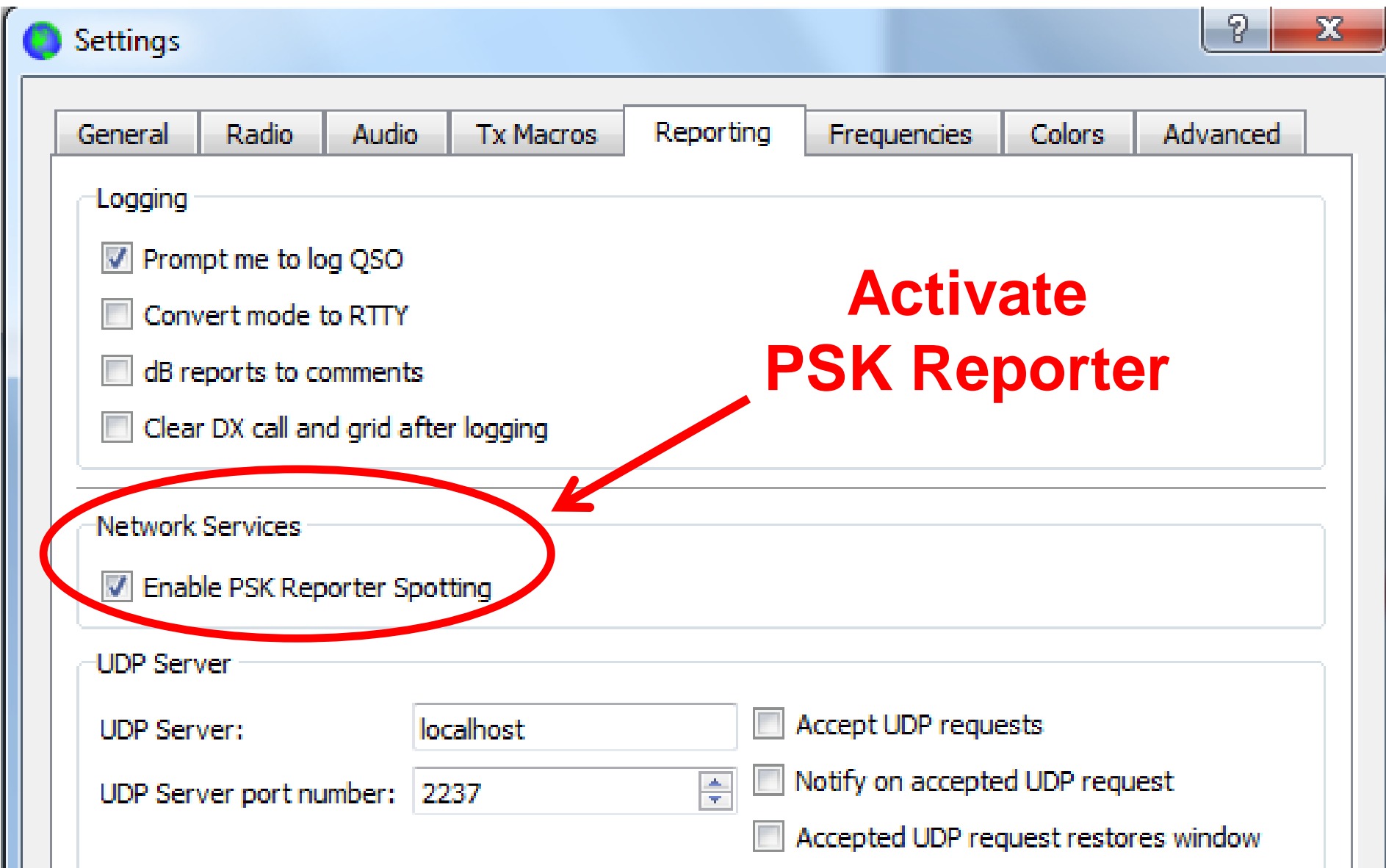
JTMSK

Last Tx: K1JT G3WDG IO92

Tx-Enable Disarmed

2/5

Logging, Reporting, UDP Server



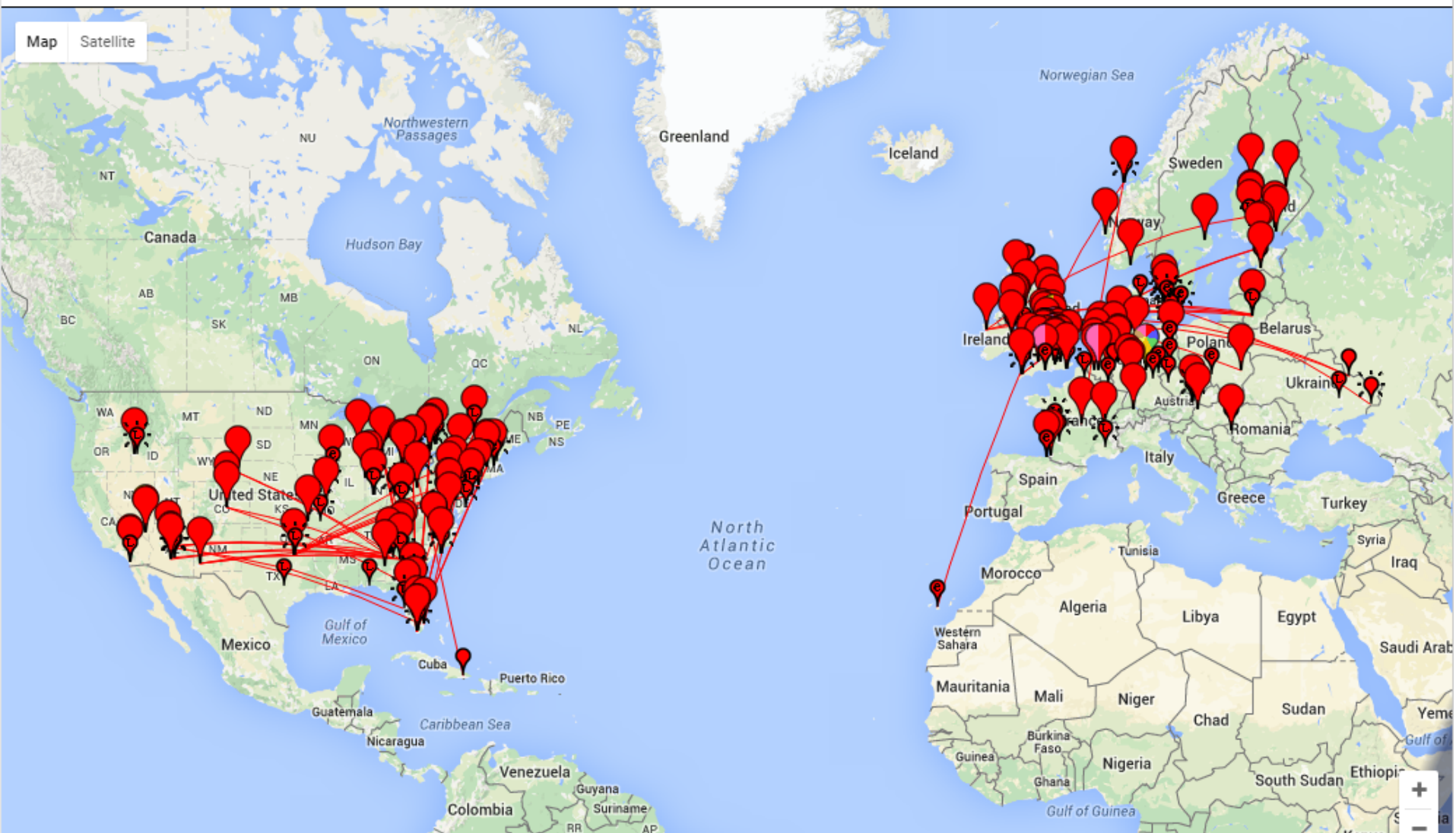
PSK Reporter: 6 m, JT modes

On , show sent by using over the last

[Display options](#) [Permalink](#)

Automatic refresh in 4 minutes. Large markers are monitors. [Display all reports.](#)

There are [121 active JT monitors](#) on 6m. [Show all JT on all bands.](#) [Show all on all bands.](#) [Legend](#)



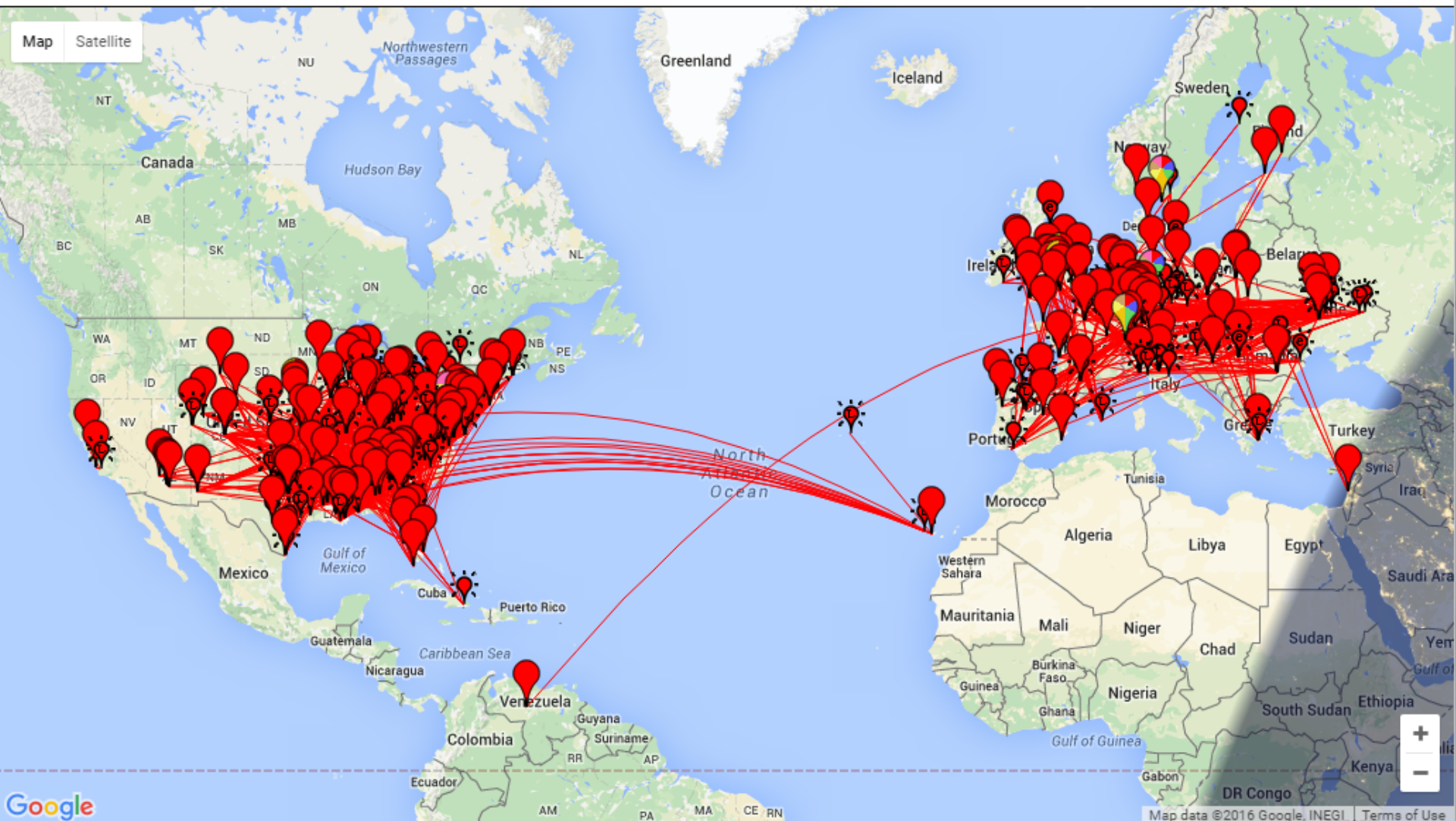
JT modes, 50 MHz

On show sent by using over the last

[Display options](#)

Automatic refresh in 5 minutes. Large markers are monitors. [Display all reports](#)

There are [202 active JT monitors](#) on 6m. [Show all JT on all bands](#). [Show all on all bands](#). [Legend](#)



EME modes

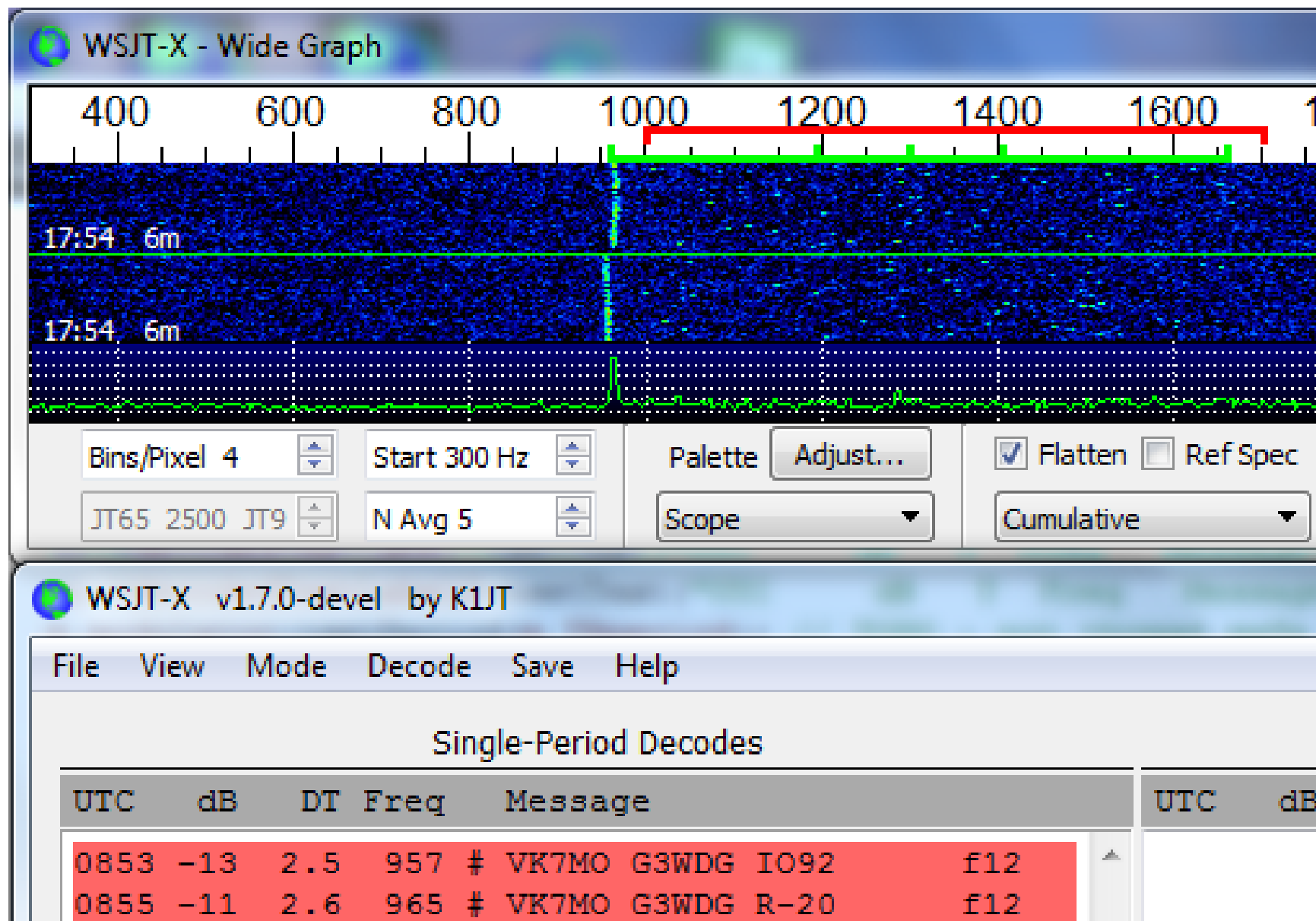
- 50 MHz: **JT65A QRA64**
- 144, 222, 432 MHz: **JT65B QRA64**
- 1296 MHz: **JT65C QRA64**
- 2.3+ GHz (depends on Doppler spread)
→ **JT65C, JT4F, JT9F, QRA64**

Don't forget: In some ways,
→ EME is easier at higher frequencies!

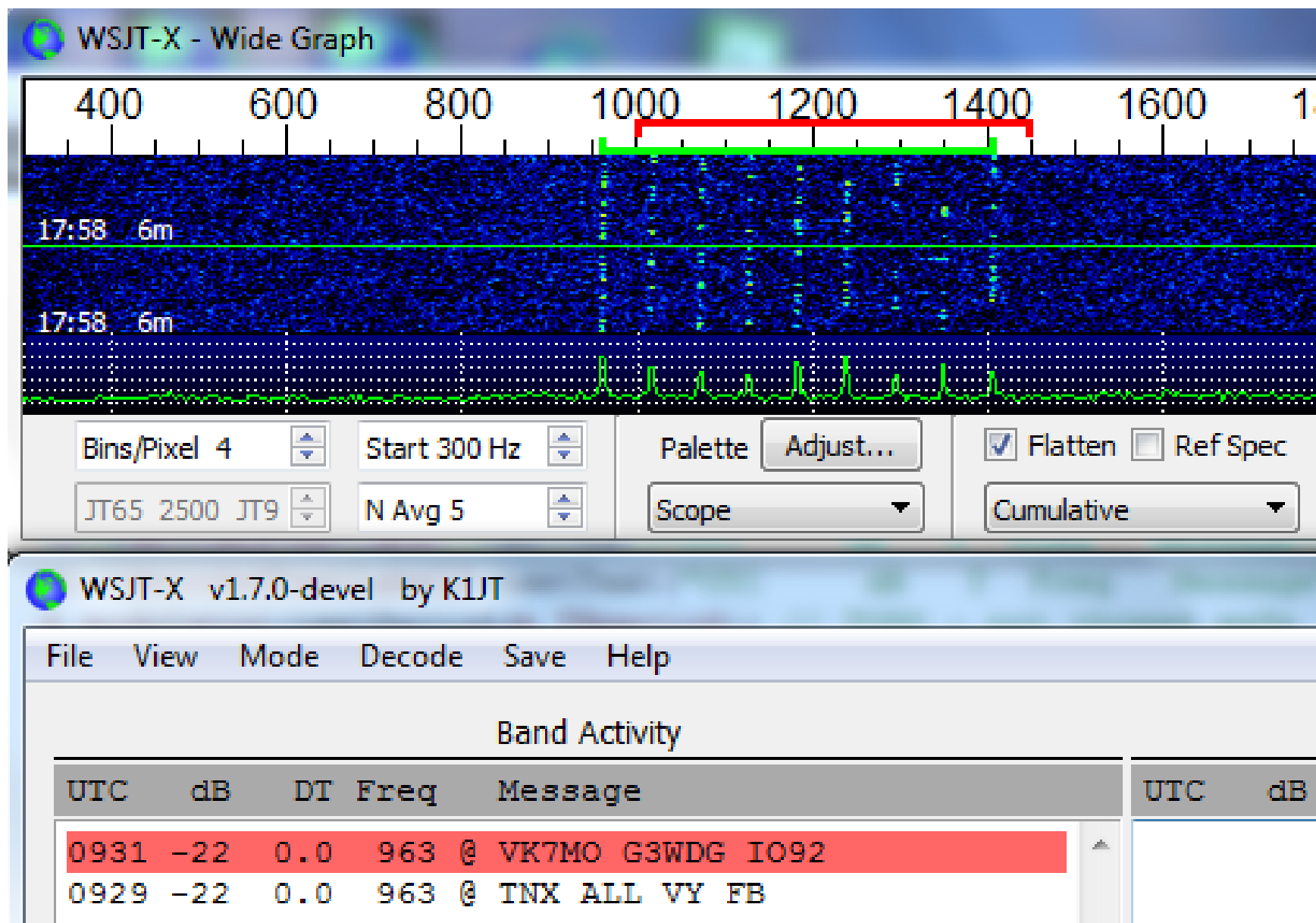
VK7MO: 10 GHz, 76 cm dish



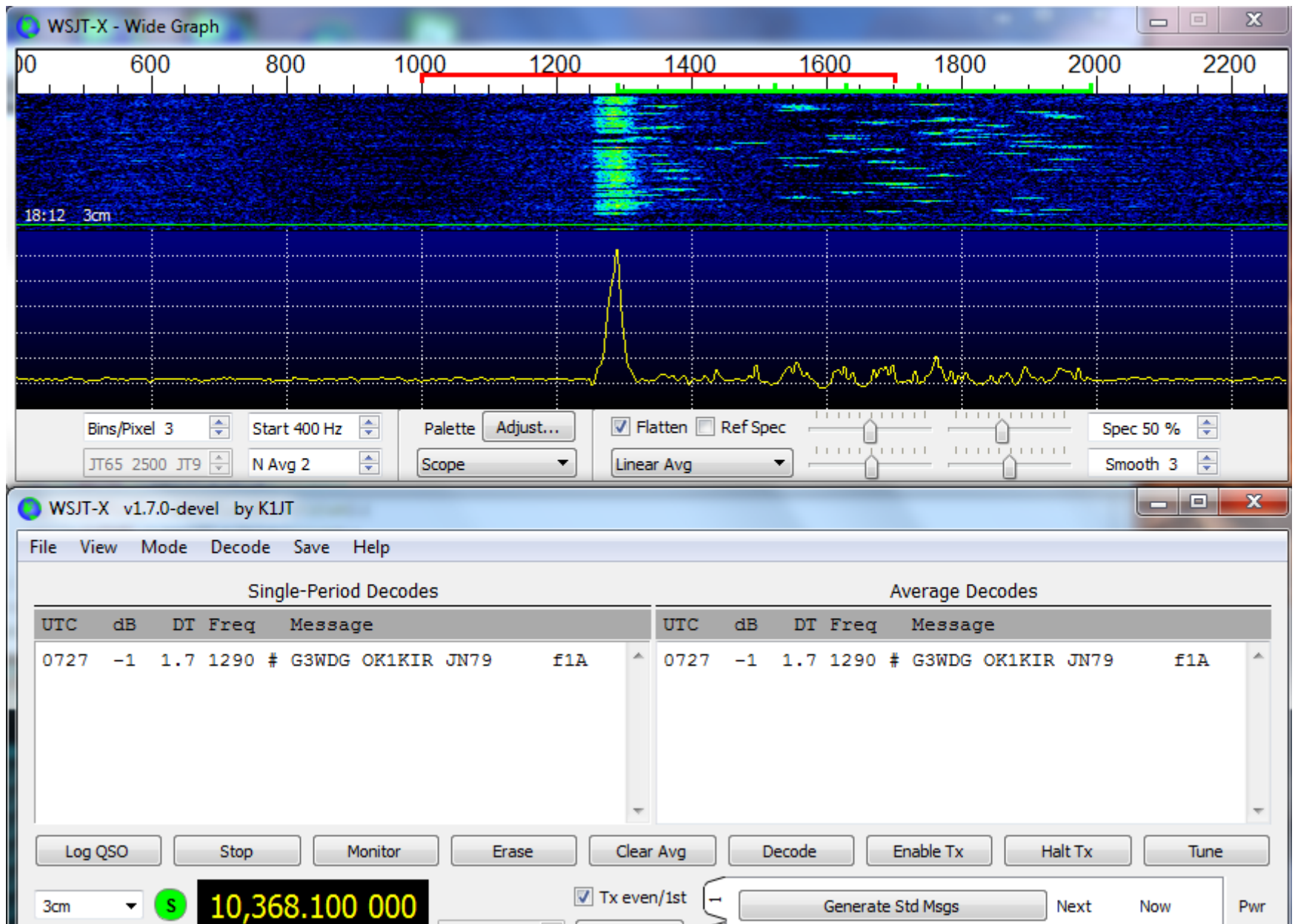
VK7MO: 10 GHz, JT65C



VK7MO: 10 GHz, JT9F



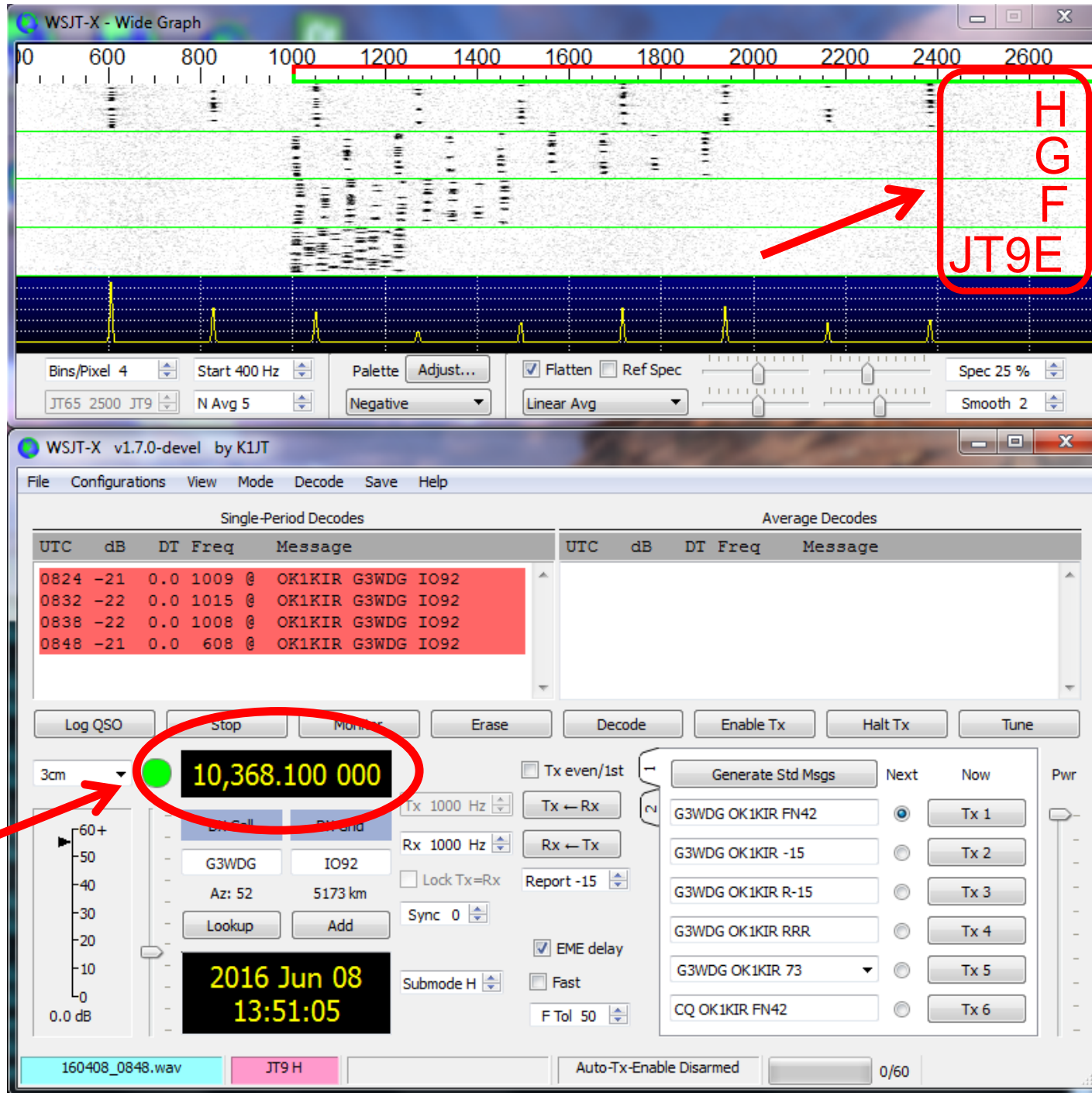
G3WDG: 10 GHz, JT65C



WSJT-X

G3WDG
received at
OK1KIR

10 GHz



QRA64

- Details in next talk: **IV3NWV**
- Q-ary (63,12) repeat-accumulate code
- Operationally similar to JT65
- Three 7×7 Costas arrays for sync
- Thousands of simulation tests
- Many QSOs, HF through 10 GHz

QRA64: Better than JT65!

- Better code: +1.0 to +1.5 dB
- Better sync scheme: +1.9 dB
- Additional +0.5, +1.1, +2.3, +4.2 dB using *a priori* information
- No callsign database
- Very low undetected error rate (UER)

Standard minimal QSO

CQ K1ABC FN42

K1ABC W9XYZ EN37

W9XYZ K1ABC –22

K1ABC W9XYZ R–19

W9XYZ K1ABC RRR

K1ABC W9XYZ 73

Underline → *a priori* “known”

QRA64: Measured Sensitivity

Thresholds for 50% decode probability

Full 72-bit message:	−28.1 dB
Locator or report:	−30.4 dB
Sync only:	−32.6 dB

Scatter Modes: Quick Overview

- Ionospheric scatter (6m, 4m) **JT9G,H**
- Meteor scatter (6m, 4m, 2m, ...)
→ 800 – 2100 km, any time! **JTMSK**
MSK144
- Aircraft scatter (10 GHz) **ISCAT, JT9H**
(up to ~800 km)

Meteor Scatter: Message duration

FSK441: 122 ms (18 char msg)

JTMSK: 117 or 17.5 ms

MSK144: 72 or 20 ms

The screenshot shows a software interface for Meteor Scatter. At the top are buttons: Erase, Decode, Enable Tx, Halt Tx, and Tune. On the left, a red circle highlights the 'Tx even/1st' checkbox (checked), 'Rx 1500 Hz' spinner, 'Report 26' spinner, 'CQ Rx 265' spinner, 'Sh' checkbox (checked), 'Auto Seq' checkbox (checked), 'T/R 5 s' spinner, and 'F Tol 500' spinner. The main area is a table with columns 'Generate Std Msgs', 'Next', and 'Now'. The 'Now' column has buttons labeled 'Tx 1' through 'Tx 6'. The messages in the table are: 'VE1SKY K1JT FN20', '<VE1SKY K1JT> 26', '<VE1SKY K1JT> R26', '<VE1SKY K1JT> RRR', '<VE1SKY K1JT> 73', and 'CQ K1JT FN20'. The first four messages are highlighted in cyan. To the right of the table is a vertical 'Pwr' slider.

Generate Std Msgs	Next	Now
VE1SKY K1JT FN20	<input checked="" type="radio"/>	Tx 1
<VE1SKY K1JT> 26	<input type="radio"/>	Tx 2
<VE1SKY K1JT> R26	<input type="radio"/>	Tx 3
<VE1SKY K1JT> RRR	<input type="radio"/>	Tx 4
<VE1SKY K1JT> 73	<input type="radio"/>	Tx 5
CQ K1JT FN20	<input type="radio"/>	Tx 6

MSK144 short messages

CQ K1ABC FN42

K1ABC W9XYZ EN37

W9XYZ K1ABC -03

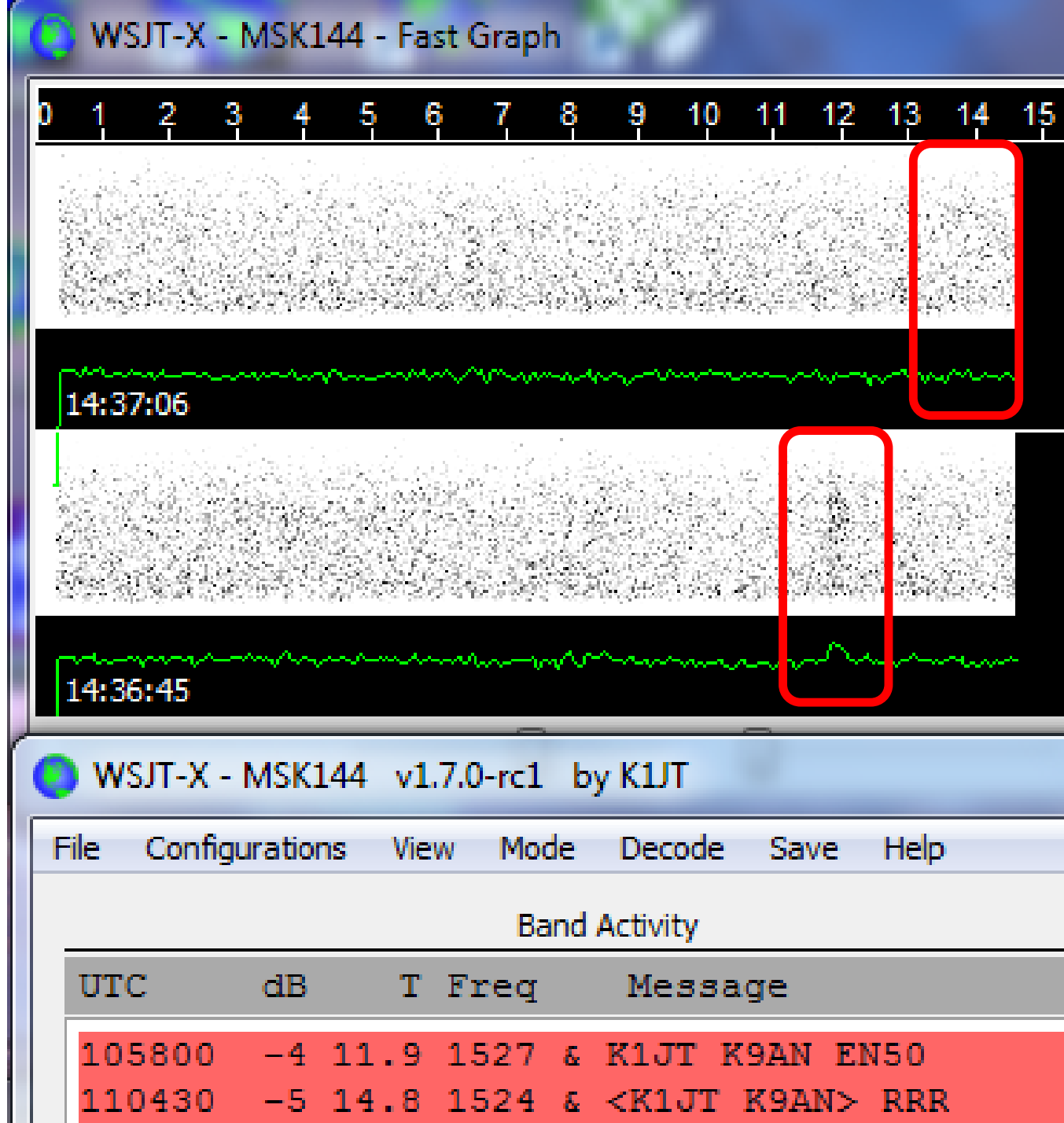
<K1ABC W9XYZ> R+03

<W9XYZ K1ABC> RRR

<K1ABC W9XYZ> 73

MSK144

Copy at
 $S/N = -4$,
 -5 dB



Still to Come ...

WSJT-X Version 1.7

- Updated User Guide
- WSJT-X v1.7-rc2
- v1.7 General Release

MAP64

- Inclusion of QRA64

Operating Advice

- Meteor scatter: **MSK144**
- Other scatter modes: **MSK144,**
Fast JT9, ISCAT
- EME at VHF/UHF: **QRA64**
- EME ($w > 50$ Hz): **JT4, JT9**

Special Acknowledgments

WSJT-X has **many** contributors!

Special thanks for recent efforts to:

G4WJS: Rig control, program structure

K9AN: FT decoder, MSK144

IV3NWV: QRA64 internals

KI7MT: Software developers kit

VE1SKY, G3WDG, VK7MO, OK1KIR: Tests